

Overview of NASA MSFC and UAH Space Weather Modeling and Data Efforts

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Outline

- ▶ Overview of capabilities
- ▶ Research / model development
- ▶ Applied space weather support
- ▶ Testing capabilities

Overview

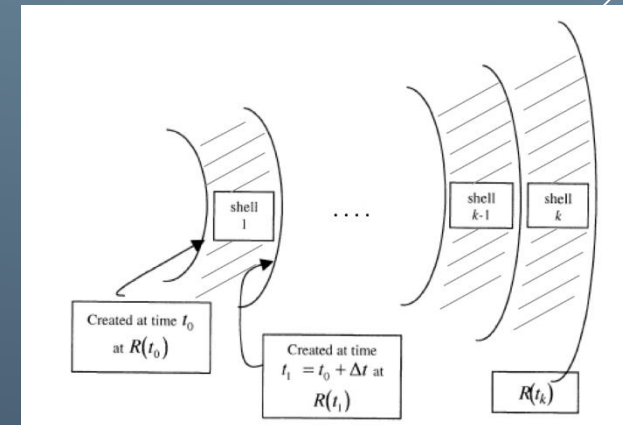
- ▶ Support all phases of the mission cycle for space weather and space environments.
 - ▶ Research
 - ▶ Testing
 - ▶ Model development
 - ▶ Design
 - ▶ Environment definition
 - ▶ Radiation, charging analyses
 - ▶ Launch availability - LCC
 - ▶ Anomaly investigation
 - ▶ Operations

Particle Acceleration and Transport in the Heliosphere (PATH) Model

- ▶ A dynamical time-dependent model of particle acceleration at a propagating, evolving interplanetary shock developed to understand solar energetic particle (SEP) events in the near-Earth environment – from 0.1 AU to several AU
- ▶ Instantaneous particle spectra at the shock front are obtained by solving the transport equation using the total diffusion coefficient κ_{ij} , which is a function of the parallel and perpendicular diffusion coefficients.

$$\underbrace{\frac{\partial f}{\partial t} + v_{w,i} \frac{\partial f}{\partial x_i}}_{\text{convection}} - \underbrace{\frac{\partial}{\partial x_i} \kappa_{ij} \frac{\partial f}{\partial x_j}}_{\text{diffusion}} + \underbrace{v_{D,i} \frac{\partial f}{\partial x_i}}_{\text{drift}} - \underbrace{\frac{1}{3} \frac{\partial v_{w,i}}{\partial x_i} \frac{\partial f}{\partial \ln p}}_{\text{energy change}} = \underbrace{Q}_{\text{source term}}$$

- ▶ Numerical shock is generated to represent a CME driven shock.
- ▶ Nest shells evolve (expand adiabatically and experience convection)
- ▶ At each point in time, t_k , model can determine:
 - ▶ Particle injection energy (via diffusive shock acceleration mechanism) and injection rate,
 - ▶ E_{max} , diffusion coefficient, wave intensity velocity, density, temperature, shock compression ratio, etc.
 - ▶ Energetic particle spectra at all spatial and temporal locations,
 - ▶ Dynamical distribution of particles that escape upstream and downstream from the evolving shock complex

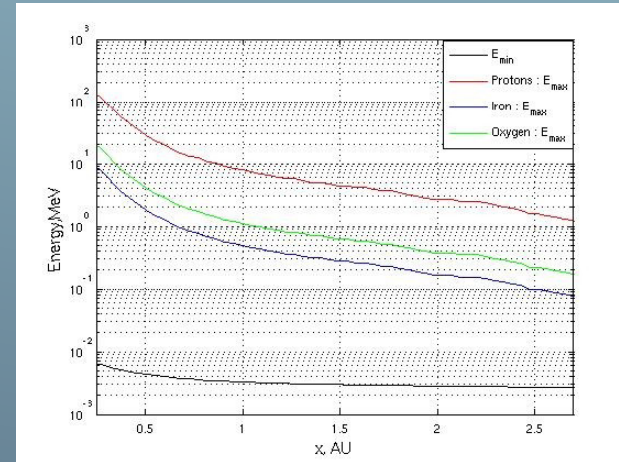


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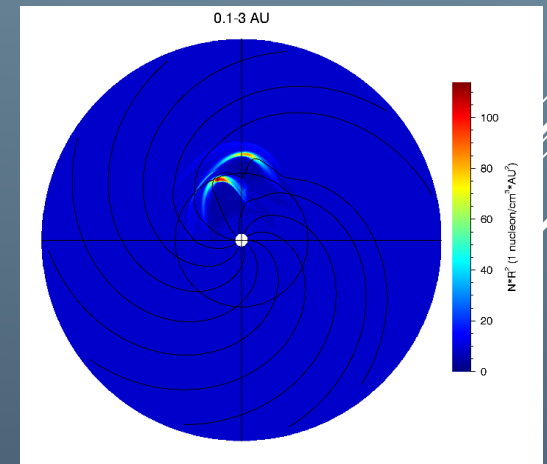
PATH Model

2/2

- ▶ A time-dependent model of shock wave propagation (1- and 2-D), local particle injection, Fermi acceleration at the shock, and non-diffusive transport in the IP medium does remarkably well in describing observed SEP events: This includes spectra, intensity profiles, anisotropies.
- ▶ Can model heavy ion acceleration and transport in gradual events, even understanding differences in Fe / O ratios, for example.
- ▶ We have begun to model mixed events to explore the consequences of a pre-accelerated particle population (from flares, for example) and have also related this to the timing of flare – CME events.
- ▶ Incorporates:
 - ▶ incorporates both solar flare and shock-accelerated solar wind suprathermal particles.
 - ▶ Arbitrary theta Bn and r (shock strength),
 - ▶ particle transport as they escape from the shock,
 - ▶ protons and heavy ions



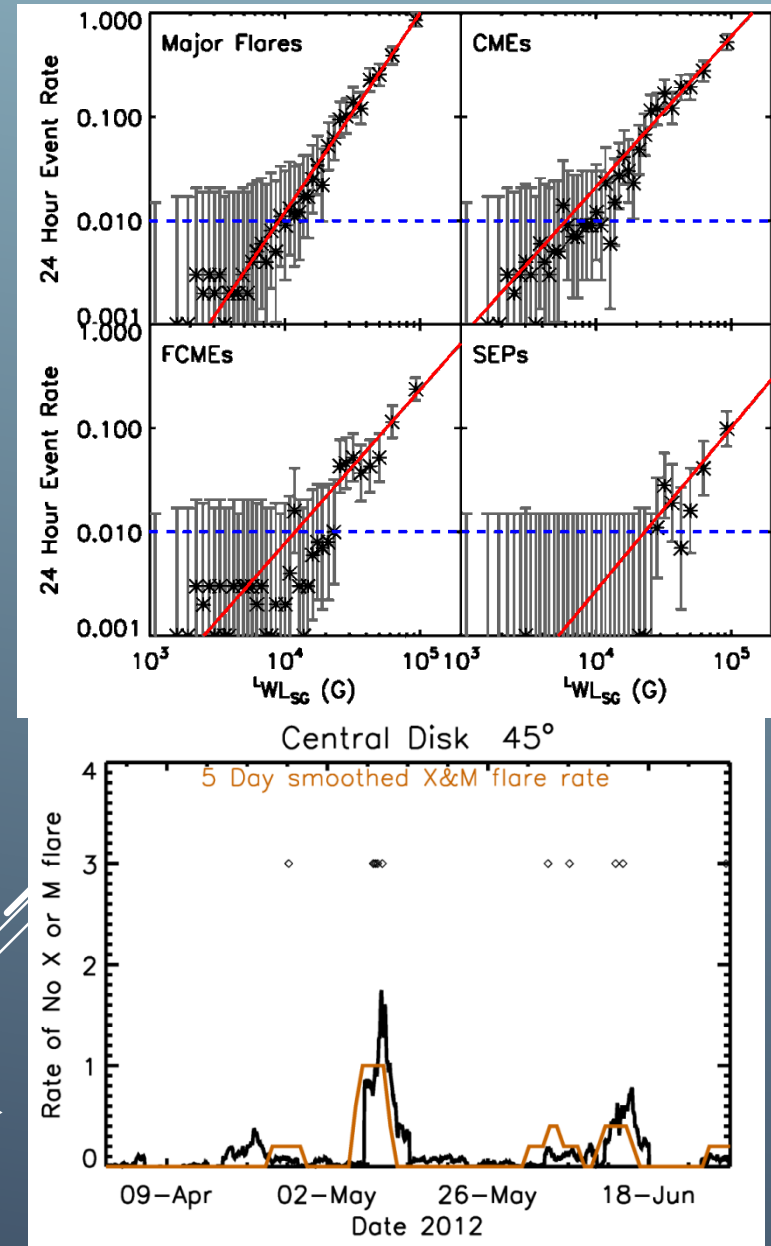
SEP Event # 215 (shock arrival at ACE: Sept. 29, 2001, 09:06 UT) , Verkhoglyadova et al. 2007



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MAG4 (Magnetogram Forecast)

- MAG4 is a R20 project developing space weather forecast tool for NASA/SRAG, with access to NOAA, Air Force, and CCMC.
 - It downloads HMI LOS or vector magnetograms, as well as recent flare history.
 - It measures a free-energy proxy.
 - The free-energy cannot be measured accurately with present instrumentation.
 - The model uses empirically derived forecast curve to predict event rates.
 - It presents the predicted event rates graphically, and in output files.
 - Graphical on next slide
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- Predicted X&M-class flare rate versus actual smoothed rate.



Comparison of Safe and Not Safe Days

June 26, 2013

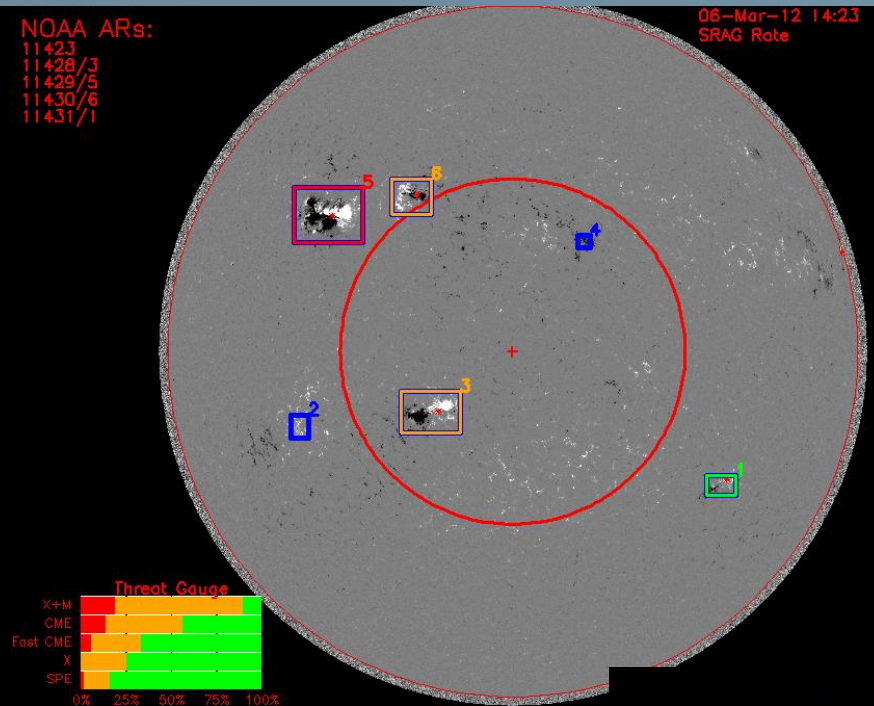
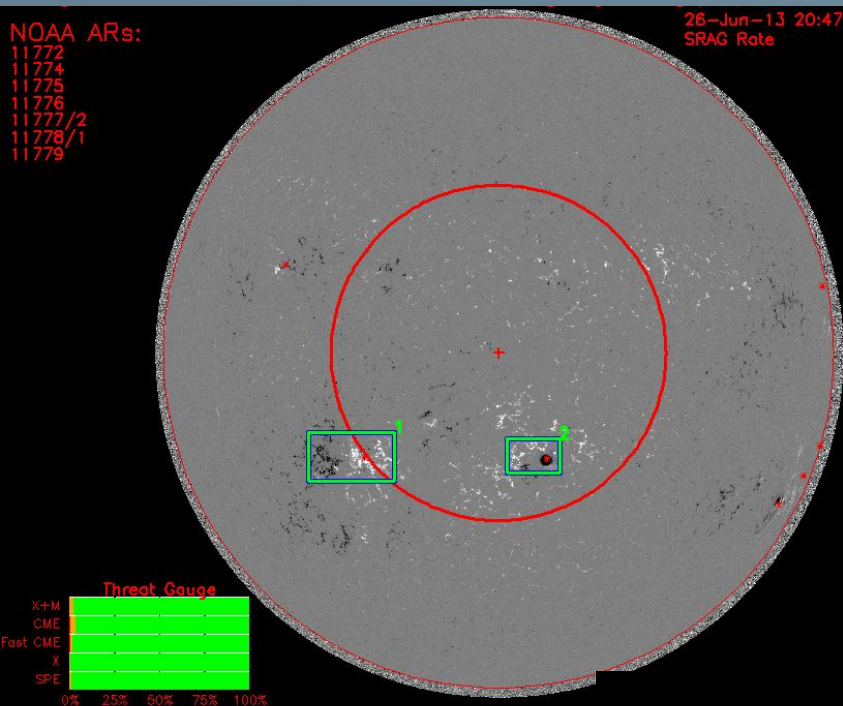
C1, C1.5 flares

March 7, 2012

X5.4, X1.3, C1.6

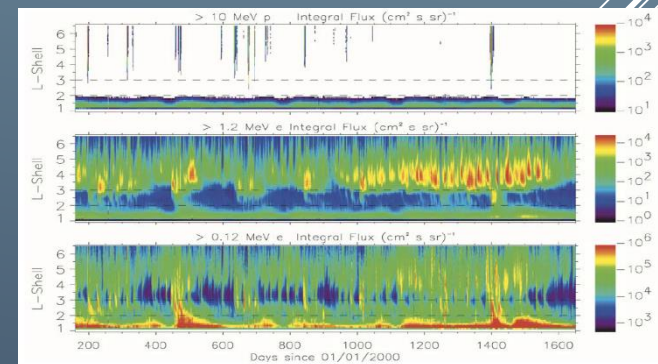
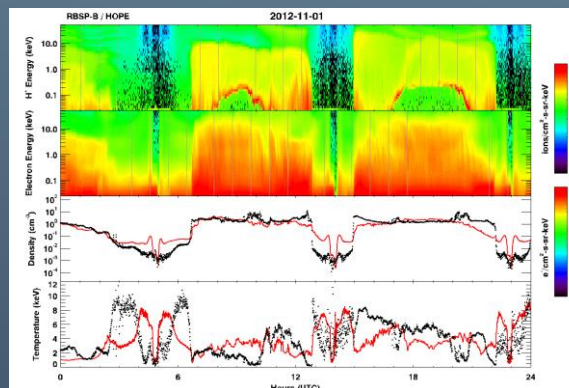
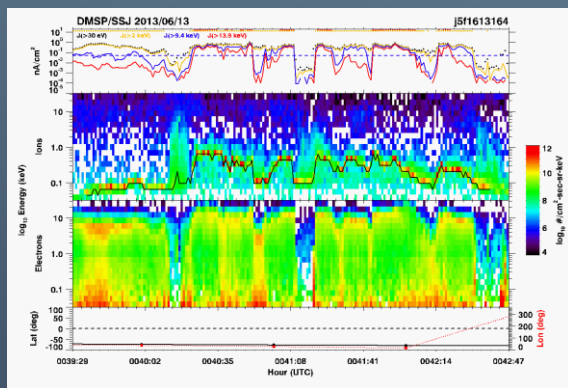
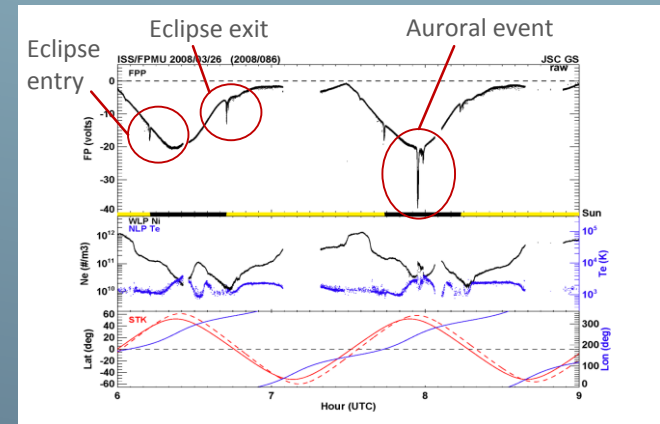
CME 2684, 1825 km/sec,

Solar Energetic Proton Event reaches 6530
particle flux unit >10MeV



Marshall/EV44 Applied Space Weather Support

- ▶ Environment Definition for Spacecraft Design
- ▶ Modeling and Analysis
- ▶ Applied Space Weather Support
 - ▶ Anomaly investigations
 - ▶ Operational Support
- ▶ Routinely use observations for: polar, radiation belts, GEO, LEO, and interplanetary environments

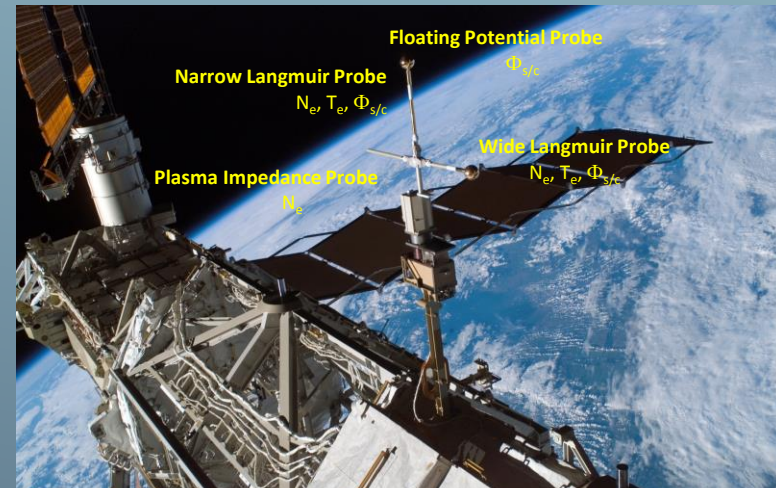


Brautigam et al., 2004

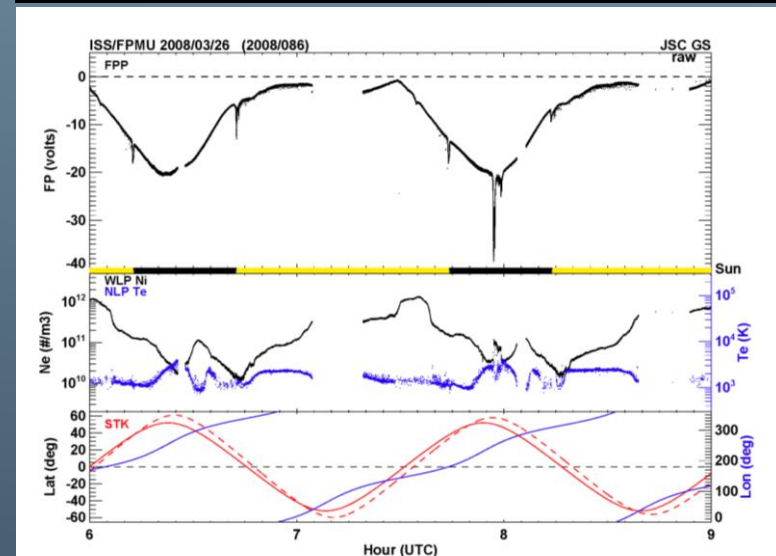
Applied Space Weather Support - ISS

- ▶ International Space Station (ISS) Floating Potential Measurement Unit (FPMU)
 - ▶ Instrument suite for monitoring ISS charging, plasma environments
 - ▶ Monitor visiting vehicle and payload charging
 - ▶ Characterize US high voltage (160V) solar array interactions with LEO plasma environment
 - ▶ Anomaly investigation
- ▶ Try to collect ISS charging data during geomagnetic storm periods in order to have information for the extreme environments

Requires a strategy to improve odds of operating FPMU during geomagnetic storm periods.



FPMU designed and built by Space Dynamics Laboratory (Logan, UT) on contract to NASA JSC



26 March 2008: FPMU captures auroral charging data during operations in support of STS-123 ISS and ATV docking

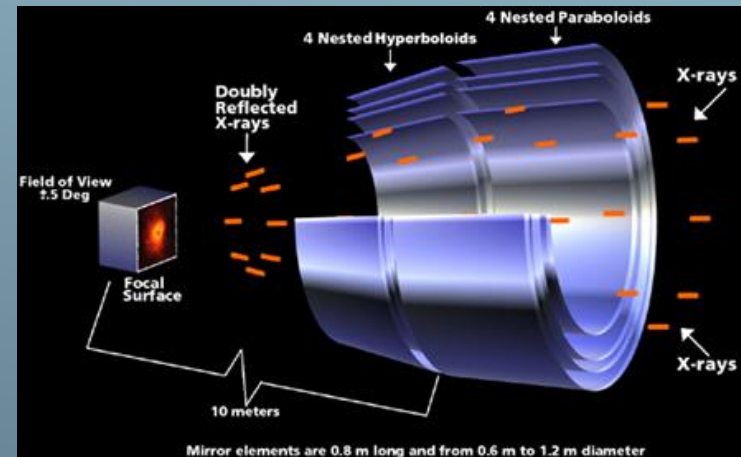
Applied Space Weather Support – Chandra

► Mitigation strategy for ACIS degradation issue

- Schedule observations in low proton flux environments

► Chandra Radiation Model

- Uses data from Geotail (EPIC/ICS instrument) and Polar (CEPPAD/IPS) spacecraft to populate the model.



	Geotail				Polar		
P3/H ⁺	77.3	-	107.4	6/H ⁺	87.7	102.0	75.9 88.4
P4/H ⁺	107.4	-	154.3	7/H ⁺	118.0	138.0	103.0 121.0
P5/H ⁺	154.3	-	227.5	8/H ⁺	161.0	188.0	142.0 168.0
				9/H ⁺	221.0	259.0	198.0 234.0

► ACE/EPAM real time monitoring

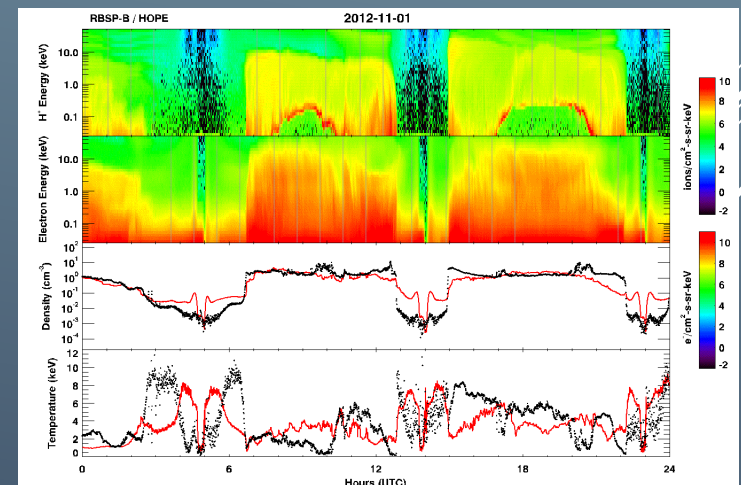
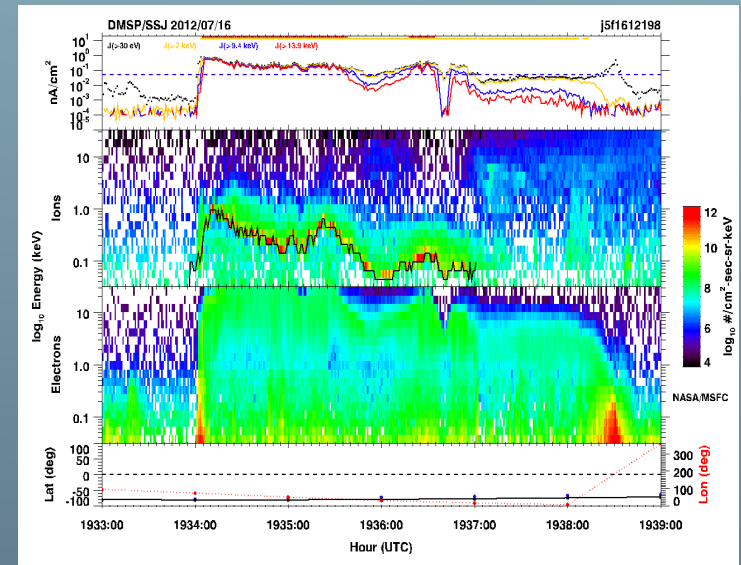
- The ACE/EPAM RTSW records are the only real-time data for detecting ~100-200 keV proton events in interplanetary space that impact the ACIS instrument

ACE (NASA)	P3'	H ⁺	115 – 195 keV	NOAA real time (5 min), manual
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Applied Space Weather Support – phenomena characterization

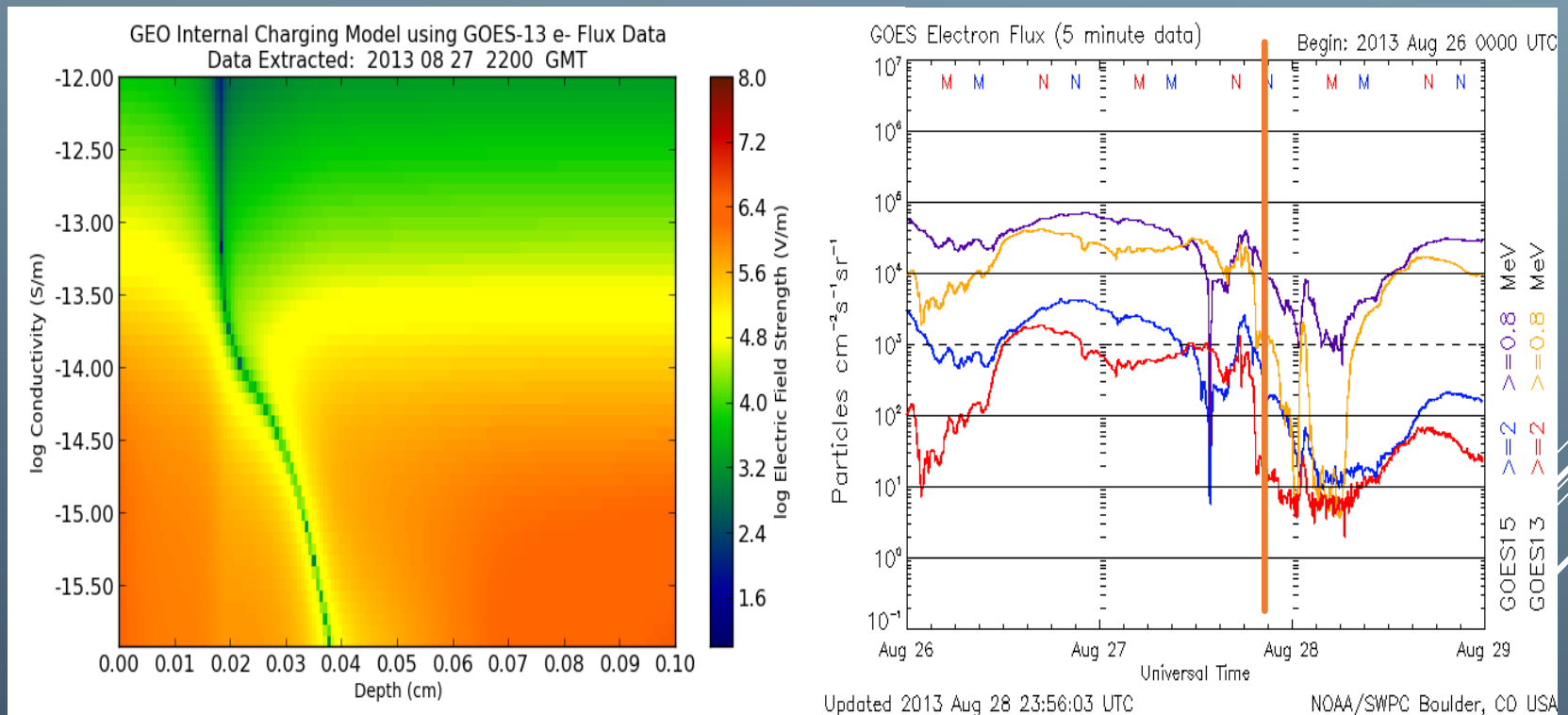
► DMSP and RBSP surface charging

- MSFC developed software tools for working with DMSP SSJ and SSIES sensor data (F6 – F18)
 - Developing automated charging event identification algorithms, useful for “charging indices”
 - Characterize extreme charging to support spacecraft design, polar orbit operations
-
- Developing a statistical database to understand the location, duration, magnitude, etc. of surface charging events.



Real Time Space Environmental Effects Tools

- ▶ Developing prototype engineering tools for evaluating effects of space environments on satellite systems
 - ▶ Geostationary orbit single event upset tool (real time version of CREME96)
 - ▶ Geostationary orbit internal charging tool

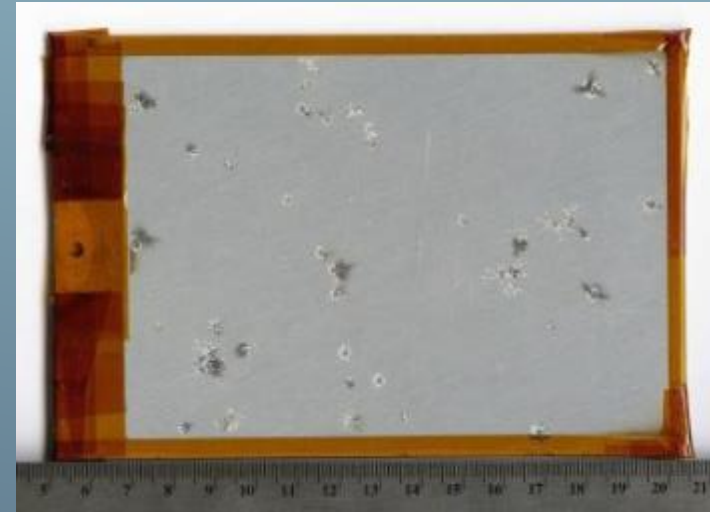


Electric fields resulting from internal (deep dielectric) charging as function of depth in dielectric material and electrical conductivity. Fields are updated at 5 minute intervals using NOAA GOES >0.8 MeV, >2.0 MeV electron data.

Space Environment Effects Testing and Calibration

Space environmental effects testing for broad spectrum of environments and effects:

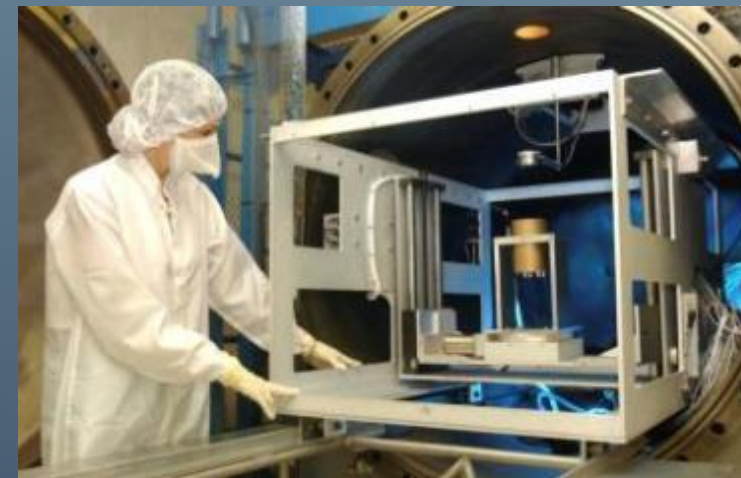
- ▶ Energetic electron, ion radiation
- ▶ Ultraviolet (UV) radiation
- ▶ High intensity solar simulator
- ▶ Spacecraft charging (surface, internal)
- ▶ Atomic oxygen
- ▶ Thermo-optical properties
- ▶ Solar array interaction with space plasma, radiation environments
- ▶ Hypervelocity (meteor/orbital debris) impacts
- ▶ Thermo/vacuum/vibration
- ▶ Contamination/outgassing



Electrostatic discharge arc damage of ISS thermal control coatings

Low Energy Electron and Ion facility (LEEIF)

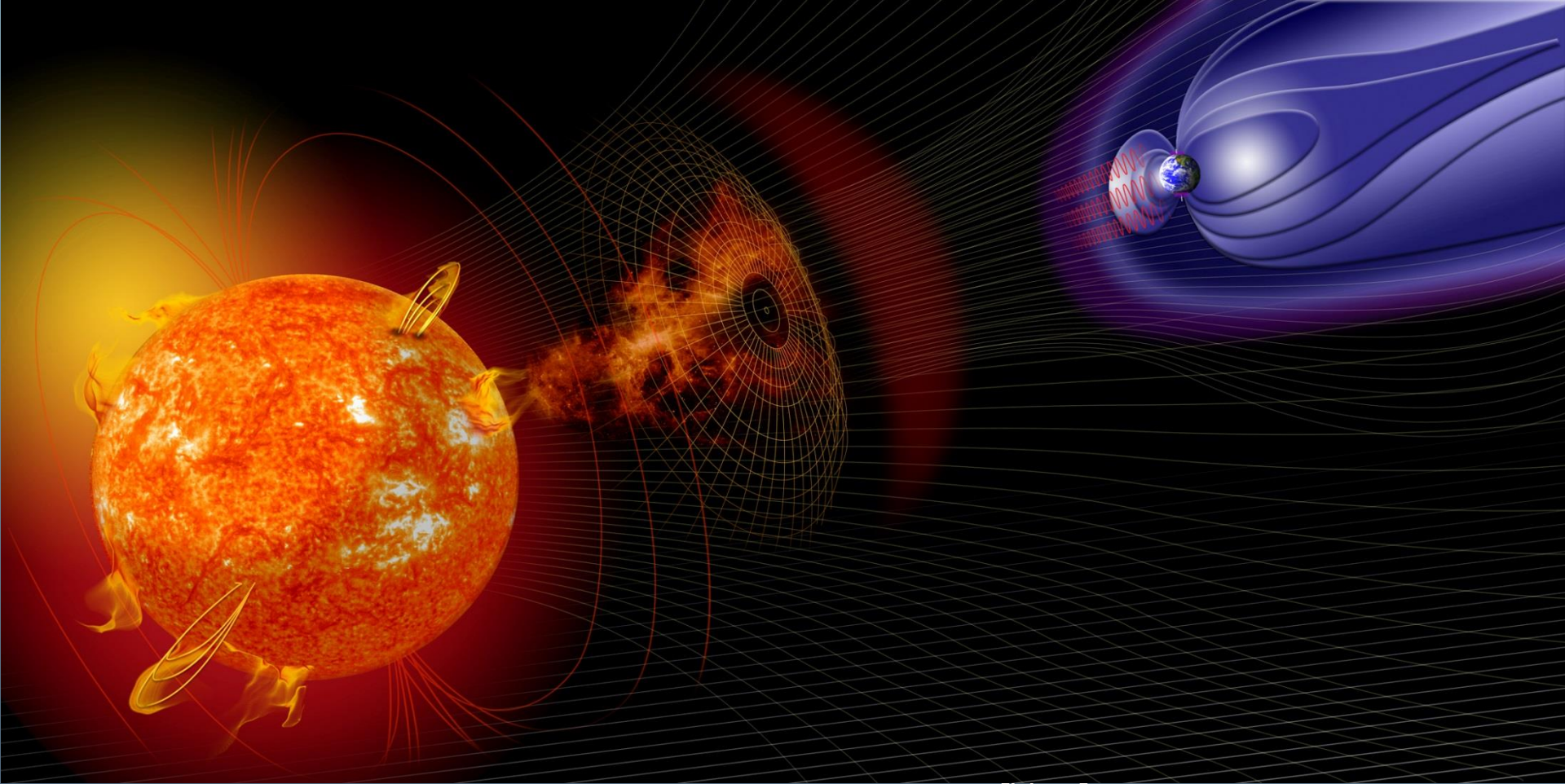
- ▶ Charged particle instrument calibration for particle energy, mass, flux, and angular acceptance
- ▶ Supports iterative design, build, and testing of space plasma instruments for variety of environments
- ▶ Electron/ion/UV sources, ISO 7 tent, ISO 5 bench, vacuum chamber, and data acquisition and analysis



LEEIF chamber with test device in mount

Summary

- ▶ MSFC and UAH are active in the modeling and development of space weather tools for R2O.
- ▶ Data from all regions of geo to interplanetary space are used for
 - ▶ Research and model development
 - ▶ Environment definition for design
 - ▶ Phenomena characterization
 - ▶ Anomaly investigation
 - ▶ Operations
 - ▶ Modeling/analysis
- ▶ Broad spectrum for space environments testing



Questions?